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Pre-bomb marine reservoir ages in the western north Pacific: Preliminary result on Kyoto University collection

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Abstract

The calibration of radiocarbon dates on marine materials involves a global marine calibration with regional corrections. The marine reservoir ages in the Western North Pacific have not been discussed, while it is quite important to determine the timing of palaeo-environmental changes as well as archaeological interpretation around this region. The lack of adequate collection of the pre-bomb shell from western north Pacific was the biggest problem. Recently we had a chance to examine specimens from an old shell collection stored in Kyoto University, including shell specimens from Japan, Korea, Taiwan and the Micronesia of 1920s and 1930s. We explored the possibility for usage of specimen without clear evidence of live collection by measuring 30 apparent radiocarbon ages of pre-bomb mollusk shells from 18 sites in Western North Pacific. The preliminary results showed several discrepancies with previously reported results and with each other. We have to carefully select the shell specimen that has biological signs such as articulating fulcrum. In order to exploit this big resource of pre-bomb shell collection, the new technique to distinguish fossils from live collected samples should be developed by using chemical and physical methods.

1. Introduction

The lack of accurate information on the correction of marine reservoir effect is the biggest difficulty in determining the timing of palaeo-environmental changes, which are related to the marine ecosystems and environments in the western part of North Pacific [1]. Especially in this region the upwelling of older deep sea water brought from North Atlantic by thermohaline circulation should contribute to local variation in radiocarbon contents in dissolved inorganic carbon (DIC) [2]. The evaluation of radiocarbon

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marine reservoir effect in the Western North Pacific is important not only to determine the precise absolute age of organic material that lived in surface water, such as shellfish and planktonic foraminifera, but also to understand the local and global carbon cycling.

Although the mollusk shell collected alive before atomic bomb testing would be the most reliable material to estimate the local calibration value (ΔR), few studies have been conducted for this purpose mainly because of the lack of samples under good condition. However, recently we had a chance to examine a huge shell collection stored at Kyoto University which contained samples collected in 1920s and 1930s from all over the western rim of Pacific including the Kamchatsuka peninsula, far east Russia, Japanese archipelago, Taiwan, and Micronesian islands. If these samples were adequate for evaluation of ΔR on the western Pacific coast, these would provide us the first perspective on the natural radiocarbon activities in this region. However, among this collection the samples with certain evidences for live collection were limited.

In this study, we measured apparent radiocarbon ages of shell collected in 1920s and 1930s in order to examine our sampling criteria for live collection and experimental methodology at the same time. One sample from Hawaii would make it possible to compare the apparent radiocarbon age previously reported. Further, some series of multiple samples from the same localities also compared to each other. If these series might show the coincidence, the result would be able to count for ΔR evaluation.

2. Materials and methods

A series of shell samples were part of "Hirase Shell Museum Collection" stored in Department of Geology, Kyoto University, Japan. Only samples that had the information on collected localities and years were selected for this study. The sampling locations include 18 sites at least from Kamchatsuka to Palau islands. While most of specimens had no clear biological evidences for live collection, such as articulating bivalves and accompanied soft tissue, we supposed the specimens were collected alive because these were basically collected by academic survey for taxonomic studies. The recorded species and sampling locations were shown in Table 1.

Only shells without any traits of weathering were analyzed for radiocarbon dating by the accelerator mass spectrometry (AMS) at National Institute for Environmental Studies, Tandem accelerator for Environmental Research and Radiocarbon Analysis (NIES-TERRA) [3–5]. Selection was conducted by two of the authors (MY and HK) based on megascopic observation. From each shell sample, small pieces of ca. 20 mg were collected by metal drill for both radiocarbon dating and stable isotope measurement. Each sample was reacted with 100% phosphoric acid within evacuated glass vessels at the temperature of 25°C, and carbon dioxide produced was purified cryogenically. These carbon dioxide samples were measured by using Finigan MAT 251 with dual inlet system for $\delta^{13}C$ and $\delta^{18}O$ values, and graphite samples of 1 mg reduced from CO_2 were measured at NIES-TERRA for radiocarbon dating. Details of AMS measurement are reported elsewhere [5]. In order to check the quality of preparation and measurement, all samples were prepared and measured in duplicate.

3. Results

Fig. 1 shows the result of duplicated radiocarbon analyses and stable isotopic ratios of carbon and oxygen on each mollusk shell sample. The repeated treatments indicate good agreements with each other with a few exceptions. It means that the preparation and measurements seem reasonable based on this comparison.

In order to estimate impact of the local reservoir effect, the apparent radiocarbon ages of these samples were calculated by computing the weighted averages and errors of two measurements. Then the radiocarbon reservoir ages (R) were calculated as the difference between the conventional age and the ^{14}C age of atmospheric CO_2 at the year of collection [4]. And the fluctuations from model reservoir age at each locality were estimated by following the determination by

Table 1
List of analyzed shell samples with the collection localities and years

Lab #	Family	Sampling site	Year
1	Buccinum	Off Kominato	1935
2	Buccinum	Etorofu Is.	1936
3	Nucella	Kamchatska	1926
4	Littorina	Hokkaido	1930
5	Tequla	Shimoda	1932
6	Colliesella	Pusan	1934
7	Glycymeris	Gaoxiong	1935
8	Neritina	Palau Is.	1934
9	Nucella	Hokkaido	1932
10	Rustularia	Ryukyu Is.	1934
11	Crepidula	Kamchatska	1926
12	Stomatella	Hirota	1936
13	unknown	Hokkaido	1932
14	Rustularia	Ryukyu Is.	1934
15	Euspira	Off Kominato	1935
16	Buccinum	Toyama Bay	1931
17	Japelion	Kazima-nada	1937
18	Chlamys	Oahu	1933
19	Erosaira	Jaluit	1934
20	Rasum	Kume Is.	1936
21	Thais	Kume Is.	1936
22	Stromous	Kume Is.	1936
23	Buccinum	Toyama Bay	1931
24	Fosciularia	Kume Is.	1927
25	Glycymeris	Gaoxiong	1935
26	Vanitrochus	Iyo	1934
27	Distorsio	Kii Pen,	1930
28	Pythia	Palau Is.	1934
29	Pyramidella	Kume Is.	1926
30	Pupa	Kume Is.	1926

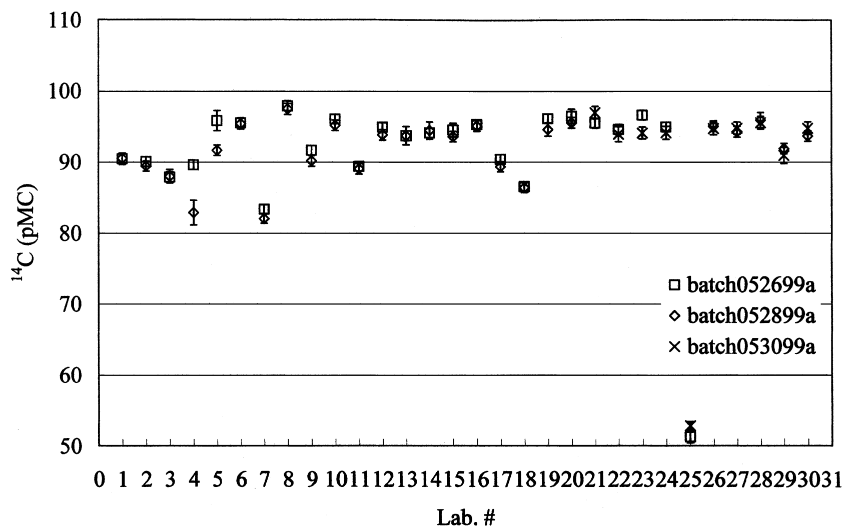

Fig. 1. Results of duplicated ^{14}C measurements. Error bars are showing one standard error of mean with each measurement.

Table 2
Results of apparent radiocarbon ages and ΔR values

Sample no.	Sampling site	Weighted 14C Age (yr BP)	R (yr)	ΔR (yr)
Pacific				
3	Kamchatska	1035±55	892	567
11	Kamchatska	915±45	772	447
2	Etorofu Is.	870±45	723	413
4	Horoizumi	950±60	813	488
9	Hokkaido	755±45	569	244
13	Hokkaido	520±55	334	9
12	Hirota	460±45	313	3
17	Kazima-nada	855±45	703	393
5	Shimoda	620±60	434	109
27	Kii Pen,	455±50	318	−7
26	Iyo	420±50	278	−47
20	Kume Is.	335±55	188	−122
21	Kume Is.	320±45	173	−137
22	Kume Is.	460±55	313	3
24	Kume Is.	435±50	286	−39
29	Kume Is.	705±55	562	237
30	Kume Is.	485±50	342	17
10	Ryukyu Is.	355±40	213	−112
14	Ryukyu Is.	480±50	338	13
7	Gaoxiong	1520±45	1370	1060
25	Gaoxiong	5200±75	5050	4740
8	Palau Is.	190±45	48	−277
28	Palau Is.	355±60	213	−112
19	Jaluit	355±45	213	−112
18	Oahu	1155±45	988	663
Sea of Japan				
16	Toyama Bay	390±45	237	−88
23	Toyama Bay	350±45	197	−128
1	Off Kominato	805±50	655	345
15	Off Kominato	500±50	350	40
6	Pusan	375±45	233	−92

Stuiver and Braziunas [6], which were expressed as ΔR values (Table 2). As these values are only preliminary discussion to examine the adequacy of samples, the precise standard error with the values was not discussed and the calibration for the ^{14}C dilution with fossil fuel (Suess effect) was not considered. Therefore, it should be noted that these values could not be used for calibration without more consideration.

4. Discussions

At first, the preliminary result of Hawaii sample showed the ΔR of 633 yr, which was quite different from the previously reported ΔR value of 115 ± 50 [7]. The previous result was also based on the single measurement [8] and it is able to observe the clear discrepancy in local calibration impact within small locality, such as the case of Long Island Sound [1]. However, the discrepancy between our result and the previous study means that the sample from Hawaii did not support our assumption that the Hirase collection was collected alive. Furthermore, the number of shell samples collected from Kume Island, a small island in Ryukyu Islands, also shows a big distribution of ΔR values from −122 to +237. In the case of Kume island where the coral lagoon is well developed, we have to consider the substantial contribution of the water input from land, which could make contribution for both directions by the hard water effect or the effect of precipitation. We have to examine the oxygen isotope values to check these effects. At last, one sample from Taiwan (sample no. 25) indicated an apparent radiocarbon age of 5200 ± 75 yr BP that is much older than oldest surface water. These results clearly show that the megascopic observation was not adequate to select the samples collected alive.

However, four samples form the Hokkaido and far-east Russia show the ΔR from 400 to 500 yr. While the other two values were much lower, the average ΔR for this locality (358 ± 188 yr) is consistent with 482 yr correction estimated by the archaeological pair of charcoal and shell from the Kitakogane site (4800 ± 140 yr BP with charcoal), Hokkaido [9]. It may be possible to explain the variation on the Pacific coast, from −47 to 393 yr by the mobility of the subpolar front in this region, which would affect the masses of upwelling. Although these topics will be discussed in the coming papers, at this moment it is first required for oceanographic discussions to certify that the collected year meant the year of death.

If we would apply biological criteria of live collection for this Hirase collection and could get a number of shells collected alive certainly, this collection had great potential to contribute fruitful information on the marine reservoir corrections in western north Pacific. Since only a part of the huge shell collection has been inspected, we should conduct the sample selection with revised severe criteria based on biological evidence of live collection. At the same time, we have to develop a new technique to identify the diagenetic alteration in the calcite crystal by using XRD, for example, and other kinds of parameters to show the fidelity of status at the collection.

5. Conclusion

As the first step for estimation of ΔR values in western north Pacific, we reported preliminary results on Hirase shell collection of Kyoto University. As this collection was collected mainly for biological research, we supposed that most samples should have been live collected and that it was possible to apply radiocarbon age correction, even without biological evidence to live collecting. However, the apparent radiocarbon ages and computed ΔR values showed that this collection might not consist of only live collected shells. The oxygen isotopes should be measured for examining the effect of hard water from land and precipitation, which had chance of local fluctuation. For the next step to determine the accurate calibration values for this region, we have to select the shell samples showing evident biological signs that the collected year was the year of shell's death. At the same time, the new estimation for sampling should be investigated by using physical chemical techniques such as crystallography to exploit the big amount of remaining collection resources.

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